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THEORETICAL TECHNOLOGY TRANSFER MEASURES FROM RISK MANAGEMENT

LANNY ALAN JINES, P.E.

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Lanny A. Jines

LANNY A. JINES, Ph.D.,P.E.
Senior Aerospace Engineer

Lawrence A. Kosiba

Lt Col Lawrence A. Kosiba
Division Chief Technology Transfer

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This study addresses the goal of managing the future by combining a promising metric, strategic planning, probability encoding, risk management, and the Taguchi Design of Experiments technique into a new "out of the box" methodology for program management. Although the methodology is applicable to many large programs, the United States military technology transfer program partnering Department of Defense laboratories with civilian industries was chosen as the focus for the demonstration. The method demonstrated goes beyond current documented attempts at metric development within the federal program. The result of the research yields useful management information for the technology transfer activity of the Air Force Wright Laboratory. Transferring military technology to civilian industry results in products and services solving deficiencies in food supply, shelter, education, health care, transportation and recreation while simultaneously contributing toward the attaintment of national employment goals yet assuring new capabilities for civil security and national defense.

The Wright Laboratory investment in mission related research and development programs which also show promise for potential future technology transfer will benefit from informed management making good decisions. The ability to predict the necessary investment funds to accomplish Cooperative Research and Development Agreements through a method capable of measurement by a proposed metric results from this Program Demonstrating Excellence. This new theoretical approach toward management of federal laboratory research and development programs results in a new methodology grounded in the theory of risk analysis capable of addressing uncertainty as found in technology transfer.

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Theoretical Technology Transfer Measures from Risk Management

Project Demonstrating Excellence

BY

LANNY ALAN JINES
ID # 97002

SUBMITTED TO THE FACULTY

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Disclaimer

The views expressed in this Project Demonstrating Excellence are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. The Project Demonstrating Excellence documentation is prepared in the sponsoring U.S. Air Force Wright Laboratory Technical Report format. The preceding Standard Form 298 on page 2 contains an abstract limited to a two hundred (200) word maximum. This form is required for public release purposes by the U.S. Air Force Public Affairs Office as a result the Project Demonstrating Excellence sponsorship by the U.S. Air Force Wright Laboratoty. The following Project Demonstrating Excellence Abstract on page 4 is provided to meet The Union Institute requirements in partial fulfillment of The Doctor of Philosophy Degree in Engineering Management.

Project Demonstrating Excellence

Abstract

Program managers use metrics to assist their understanding of progress and accomplishments. Often the complexities of large programs result in exhaustive efforts to develop the best metric which provides upper management with a simple to understand measure of goodness or success. Too often the tasking to define a specific program metric is constrained by a limitation requiring any data collection to be minimally intrusive upon the work force or customer base. Persistence and hard work is sometimes rewarded with a validated metric that management and stakeholders accept. However, the usual result is a quantity which is misunderstood or simply not appreciated. The difficulty arises when management, holding the coveted metric in hand, realizes it has at best a good statement of past history but what it really needs is a methodology, an actual scientific method, for managing the future.

This study addresses the goal of managing the future by combining a promising metric, strategic planning, probability encoding, risk management, and the Taguchi Design of Experiments technique into a new "out of the box" methodology for program management. This management methodology demonstrates an interdisciplinary nature in that human factors and statistical processes combine in the identified components to produce a quantified measure predicting future results. Although the methodology is applicable to many large programs, the United States military technology transfer program

partnering Department of Defense laboratories with civilian industries was chosen as the focus for the demonstration. The method demonstrated goes beyond current documented attempts at metric development within the federal program. The result of the research yields useful management information for the technology transfer activity of the Air Force Wright Laboratory. Transferring military technology to civilian industry results in products and services solving deficiencies in food supply, shelter, education, health care, transportation and recreation while simultaneously contributing toward the attaintment of national employment goals yet assuring new capabilities for civil security and national defense.

The Wright Laboratory investment in mission related research and development programs which also show promise for potential future technology transfer will benefit from informed management making good decisions. The ability to predict the necessary investment funds to accomplish Cooperative Research and Development Agreements through a method capable of measurement by a proposed metric results from this Program Demonstrating Excellence. This new theoretical approach toward management of federal laboratory research and development programs results in a new methodology grounded in the theory of risk analysis capable of addressing uncertainty as found in technology transfer.

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Dedication

This Project Demonstrating Excellence for the Doctor of Philosophy in Engineering Management is dedicated to my wife, Karen and daughters, Kelly and Traci. Their patience toward my task of completing this phase of a life-long learning experience is most appreciated. Additionally, the encouragement of my colleagues at the U.S. Air Force Wright Laboratory has made the experience professionally rewarding.

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In the course of conducting research, analyzing, and authoring the Project Demonstrating Excellence for The Union Institute Doctor of Philosophy Degree Program in Engineering Management, I have been influenced by the accomplishment and work of managers, human resource specialists, scientists, and engineers of the U.S. Air Force Materiel Command Wright Laboratory and the U.S. Air Force Materiel Command Wright-Patterson AFB Educational Office Campus. The U.S. Air Force Wright Laboratory Flight Dynamics Directorate and Plans Directorate sponsorship of the educational learning experience in conjunction with the support of the U.S. Air Force Materiel Command Wright-Patterson AFB Educational Office Campus administrative team have made possible this educational opportunity meeting the downsizing and "Wright-sizing" needs of the Wright Laboratory seeking to provide alternatives in cost effective and efficient academic experiences to professional technical managerial scientists and engineers.

I want to recognize the support and encouragement of Wright Laboratory personnel Mr. Edward O. Roberts, Mr. Ralph Speelman, Mr. Richard E. Colclough Jr., Col Robert Herklotz, Dr. Keith Richey, Mr. Richard C. Jones, Mr. James R. Meeker, Lt Col Lawrence A. Kosiba, Mr. William Goesch, Dr. William U. Borger, Mr. Timothy L. Dues, Mr. Terry L. Neighbor, Mr. O. L. Smithers, Dr. Vince J. Russo, Brig Gen David A. Herrelko, and Col Richard W. Davis. The administrative challenge and creative foresight of U.S. Air Force Materiel Command Wright-Patterson AFB Educational Office Campus administrator, Ms. Maggie Grace, along with the detailed work of resource specialists Ms.

Nora Ledford, and Ms. Dianne Crew were instrumental toward the successful program sponsorship and approval by the U.S. Air Force Wright Laboratory. Participants in the strategic planning internship and members of the panel of expert judges accomplishing the probably encoding data collection were: Dr. Lawrence R. Bidwell, Ms. Leila Best, Mr. Mark Chiminiello, Mr. Greg McGath, Mr. Vince Miller, Mr. Sam Rosengarten, and Ms. Kristen Schario. Their participation was instrumental to the success of this study and their efforts are most appreciated. The contribution by Clinton J. Braun, First Lieutenant, USAF, and the suggestions, cooperation, encouragement, and lengthy discussions with Mr. Roy W. Hale provided much academic enthusiasm and stimulus toward the successful completion of this Program Demonstrating Excellence.

Finally, the guidance and leadership to "focus and control" this educational experience began with the entry colloquium co-chaired by Holloway C. Sells, Ph.D., and Marlene Warner, Ph.D. The formulation of the" life long learning approach" to education which was embraced during the entry colloquium has been reinforced and enhanced by the contribution of the Doctoral Committee composed of Peter Fenner, Ph.D., Rose Duhon-Sells, Ph.D., Brig Gen Stanley J. Czyzak (Ret), D.Sc., P.E., Edward R. Mott, D.Ed., Bruce E. Laviolette, Ph.D., and Philip P. Panzarella, Ph.D., P.E.

List of Figures & Tables

Glossary

AFIT - Air Force Institute of Technology Graduate School of the Air Force located at Wright Patterson Air Force Base, OH.

AFMC - Air Force Materiel Command

AGATE - Advanced General Aviation Transport Experiments

Aggregate Demand - Aggregate demand is the total demand for goods and services in the economy. This demand is generated by expenditures on domestically produced goods and services by consumers, firms (through investments), the government, and by entities in foreign countries.[1]

ARR - Actual Rate of Return

ASC - Aeronautical Systems Center

ASTARS - A Science & Technology Action Reporting System

CRDA - Cooperative Research and Development Agreement

DoD - Department of Defense

DoE - Department of Energy

DOE - Design of Experiments

DoT - Department of Transportation

Internship - A new learning experience involving a significant portion of time directed toward professional and personal development.[2]

DSMC - Defense System Management College

FLC - Federal Laboratory Consortium

IE - Information Economics

IIR - Internal Rate of Return

IT - Information Technology

IPT - Integrated Product Team

Learning Agreement - The signed document representing a comprehensive plan designed by the learner through collaboration with the doctoral committee. This plan, as individualized by the learner, may include use of university courses, libraries, museums, private resources, professional associations, communication media, planned travel, conferences, workshops, lectures, experiences within professional work settings, constructive social action and any other services or materials needed and available may become part of the strategy for academic and personal development toward the doctoral degree.[3]

Management of Technology - The interdisciplinary combination of technical and management knowledge focused toward responsibility in technical problem solving of complex demands resulting from the social, technical, economic, and political facets of science and engineering organizations.

Metric - A measurement, taken over time, that communicates vital information about a process or activity. A metric should drive appropriate action and must be linked to a strategic plan.

NPV - Net Present Value

ORGA - Out Reach to General Aviation

ORTA - Office of Research and Technology Applications[4]

PDE - Project Demonstrating Excellence

PE - Probability Encoding

QRA - Quantified Risk Analysis

raNPV - risk adjusted NPV

Risk - The probability of an undesirable event occurring and the significance of the consequence of the occurrence.[5]

ROI - Return on Investment

Stakeholder - A person or legal entity which shares ownership in the development, execution, liability and responsibility of a concept, idea, invention, product, or process from the initial developer to the customer as end user.

Technological Progress - Technological progress refers to increases in total output per unit of input. Technological progress can take the form of: a) the same amount of inputs producing more valuable products, b) increases in the quality of inputs allowing the same

amount of inputs to produce more output, and c) the old level of output produced with fewer inputs.[6]

Technology Transfer - A process by which facilities, equipment, or other resources relating to scientific or technological developments of a federal laboratory are provided or disclosed by any means to another industrial organization, including a corporation, partnership, limited partnership, or industrial development organization; public or private foundation; nonprofit organization, including a university, or other person to enhance or promote technological or industrial innovation for a commercial or public purpose.[7]

Technology Transition - The movement of technology from R&D to first-time application.[8]

TTO - Technical Transfer Office

WL - Wright Laboratory

XP - Plans Directorate

XPT - Technology Transfer Division

1.0 Introduction

1.1 The Project Demonstrating Excellence (PDE) in partial fulfillment of requirements for The Doctor of Philosophy Degree in Engineering Management at The Union Institute focuses upon the development of management methodology for technology transfer between the Air Force Wright Laboratory (WL) and industry partners. Effective management methods will enhance the national impact achieved from the conversion of former defense weapon system technology into new products for the civilian industrial market through the process of technology transfer.

1.2 Successful management of technology transfer processes depends upon both effective metrics which measure the cost of the conversion process from research to manufacturing and prediction methods assessing the risk of new technology for future transfers. The transfer of technology from military defense laboratories has potential to create products and services solving deficiencies in food supply, shelter, education, health care, transportation and recreation while simultaneously contributing toward the attaintment of national employment goals and insuring new capabilities for civil security and national defense. Within the civilian industry of our nation, the activity cost of moving technology (e.g. technology transfer) into manufactured goods has traditionally, altlhough not in every case, been captured within overhead cost accounts. Military research laboratories have only recently begun to capitalize upon the opportunity to aggressively move research products into non-mission arenas of the civilian industry for mutual economic benefit. The

U.S. Department of Defense Air Force Materiel Command (AFMC) Aeronautical Systems Center (ASC) Wright Laboratory (WL) engages in technology transition and transfer according to applicable public law, acts, executive orders, and Air Force policy directives.[9]

1.3 The expenditure of WL resources, in terms of manpower, facilities, and funds, for the transfer of technology to companies and corporations has an impact upon the mission of the AFMC and the nation's economy. The measurement of the cost and the impact to the nation for engaging in technology transfer under the referenced mandated legislation has been a topic of numerous panel discussions, university studies, industry concerns, and a requirement for the Air Force Technology Transfer Office (TTO) Integrated Product Team (IPT) as well as the WL Plans Directorate (WL/XP). Only recently have affordable non-intrusive cost metrics[10,11] been identified which theoretically notes an understanding of the impact upon the nation's economy generated by technology transfer activities of government (i.e., federal) research laboratories.

1.4 Members of the U.S. Congress, Departments of Defense (DoD), Energy (DoE), Transportation (DoT), Federal Laboratory Consortium (FLC), and industry partners are the intended audience for the results of this PDE in Engineering Management. The results are intended to assist all levels of technology transfer stakeholders (e.g.., managers, researchers, manufacturers) and corporate marketing functions with management tools and understanding for making product development decisions. The opportunity to transfer high cost research and development program technologies into new products

solving many of the difficult problems in the nation is accomplished through new strategies focusing resources and benefits for mutual gain in food production, transportation, education, health care, housing, public safety and national security. In general the technology sharing efforts continue in a cooperative atmosphere between government laboratories and the civilian industry as long as the necessary theories, concepts, models, tools and information becomes available to measure the success and anticipate future costs while providing accountability to our nation's legislature. By developing a measurement prediction method based upon risk assessment techniques, the management of future technology transfer programs will be more effective and efficient.

2.0 Background

2.1 The need to measure progress toward an objective arises as soon as an objective is established. If the objective is at the interest level warranting national attention, then the determination of the various attributes of a metric become very important as well as the timeliness and intended use by the customer seeking the information. "Having established the national objective of increased technology transfer from federal laboratories to private industry, the government is interested in discriminating between those organizations that are effective in technology transfer and those that are not. The Executive and Legislative Branches of the Federal Government must monitor performance for budgetary, political, and other reasons. In the case of technology transfer, private companies also will monitor performance, if only to determine whether they are missing an opportunity."[12] It has been proposed by Beverly J. Berger, Ph.D., the Washington D.C. representative of the FLC for Technology Transfer that creativity is required to measure progress in technology transfer. Further, it will involve knowing whether cultural change is taking place in the government and in the private sector through objectives which provide both standards and incentives for technology transfer. Importantly, Dr. Berger asks "how do we measure the process of technology transfer without distorting or impeding it ?"[13]

2.2 The March 1995 issue of *The Chronicle of Higher Education* presented findings to the question "Does Technology Policy Create or Eliminate Good Jobs?"[14] The referenced study addressed measures of "...the economic benefits of a particular event by

comparing the state of the economy after the event has happened to the state of the economy assuming the event had not happened."[15] The authors explore changes in total output produced for both the long run and short run economic impact as well as changes in product mix influenced by market forces, self sufficiency vs free trade arguments, and issues of national defense and economic security.[16] Conclusions are reached about technology transfer activities and their effect upon the economy. Although broad in concept, the conclusions support a hierarchy in understanding the effects beginning with commercialized technology, i.e., the technology used by firms in manufacturing, and progressing through issues of job creations, regional economic focus and national economic focus.[17]

2.3 The scope of this study focuses upon the Air Force WL technology transfer process. Beginning with a review of the foundations of 1980 congressional legislation, language and intent for "our country's industries, academia, and state and local government agencies..." to "... greatly benefit from sharing our [federal laboratories] technical knowledge and expertise,"[18] the study proceeds through the available literature drawing upon a decade of process attempts through legal instruments, program reviews, congressional clarifications, legislative revisions and department directives establishing the Air Force Materiel Command (AFMC) Aeronautical Systems Center (ASC) Wright Laboratory (WL) Office of Research Technology Applications (ORTA) and the Plans Directorate (XP) Technology Transfer Division (XPT). A specific look into the processes and activities implementing technology transfer at the functional level where basic

research, engineering research and development, advanced demonstration projects, and transition to field systems occurrs results in new insight, understanding, tools, and methods to the determine the taxpayers' cost and the nation's benefit from government laboratory technology transfer.

2.4 Initial findings from literature reviews, personal interviews, and discussions note that students of technology transfer processes have defined, analyzed, and proposed numerous findings and approaches for implementation instruments,[19] factors affecting technology transfer,[20] understanding the commercial sector,[21] and exploratory understanding of technology transfer concepts, federal infrastructure, and process models.[22] An extensive literature search, including a personal interview, capture the essence of the importance of technology transfer,[23] the status of technology transfer capabilities as established through case studies,[24] and the current status of technology transfer metrics development.[25] More importantly the determination that management methodologies using these existing or newly emerging metric tools for proactive technology transfer management were missing -- simply not addressed by the academic community. This fact was not surprising since the proposed development of adequate non-intrusive metrics emerged via an academic graduate school publication[26] in September 1996 and through a personal interview[27] conducted during April 1997. The timely development of an engineering management approach for technology transfer decision making within WL has the potential to define and benchmark processes applicable to all government laboratories.

2.5 A review of these new technology transfer metric approaches reveals the degree of complexity and the need for manageable non-intrusive measurement methods. The Cooperative Research Development Agreement (CRDA) information of record within WL has served as a source of data for students from The Alfred P. Sloan School of Management and the School of Engineering at the Massachusetts Institute of Technology,[28] and The Air Force Institute of Technology (AFIT) Graduate School of Logistics and Acquisition Management for studies concerning the technology transfer process.[29, 30, 31, 32] The work by First Lieutenant Clinton J. Braun in 1996 investigated the technology transfer process for opportunities to measure return on investment (ROI) based upon a cost/benefit analysis model modified to include intangible benefits. His review of methodologies for ranking projects included techniques for projected cash flow, i.e. payback periods, accounting rate of return (ARR), net present value (NPV), and internal rate of return (IRR).[33, 34] The study noted the difficult task of applying conventional ROI methodology to the technology transfer process. It is highly cumbersome and intrusive to develop total estimates of a technology transfer project's actual or estimated revenues and benefits. It is the technology transfer's intangible benefits among participating partners which cannot be directly related to project dollars most easily understandable by decision makers. The intangible benefits are often the quality of life improvement processes achieved through expert discussion and idea exchanges which assist an industry entity without formal recognition and reimbursement. Intangible benefits are usually determined through a heuristic approach requiring significant interviewing with individuals in partnering organizations. The typical product of such

intrusions is lengthy qualitative written reports of the interview questions and responses. In order to overcome the problem that intangible benefits are sometimes considered as decision criteria, but many times are overstated, understated or not quantified, Lt Braun sought to incorporate a two step technique of identifying and quantifying intangible benefits and assigning "specified magnitudes of the value."[35] The identification and quantification of intangible benefits of technology transfer activities previous to 1995 did not exist in the pertinent literature. Lt Braun investigated developments in the information technology (IT) industry where the benefits for increasing productivity are intangible and difficult to quantify, i.e. Oracle Corporation development of a model called CB-90 which assist managers with IT investment decisions, the Mathias Schumann approach to quantifying intangible benefits for office automation,[36] and the methodology developed by Richard Pastore for information economics (IE) using a system of quantifying the intangible benefits of a project resulting in rankings based upon their expected contribution to business objectives.[37] Each of these methods have limitations in their quantification schemes as noted by Lt Braun's thesis. His approach toward resolution of the quantification of intangible benefit schemes for technology transfer came from the discipline of decision making utilizing probability encoding (PE) interview processes, i.e. P-method, V-method, or PV-method where subjects respond to points or values on scales where either probabilities remain fixed, or values remain fixed, or in the later case each varies according to the outcome or variable that is being quantified.[38] Lt Braun develops a methodology, which addresses both the tangible and intangible benefits of technology transfer, applicable for comparison of CRDA projects. Although a long way from being a

practical, useful and non-intrusive metric of technology transfer, the methodology introduced by Lt Braun does incorporate probability encoding and some of the basic risk analysis techniques presently applicable within the state-of-the-art project and performance management. See Appendix 8.1 Example CRDA Benefits Data.[39] Yet the end result is burdensome to employ and is limited to assessing technology transfer activities underway or imminent with well defined CRDA work plans.

2.6 Independent of Lt Braun's investigations, Mr. Roy W. Hale, WL/XPT, proposed a metric[40] for technology transfer processes based upon the same available set of CRDA case files. This unpublished study, initially proposed in 1995 and drafted in 1996, was defined and investigated against a randomly generated notional database of three federal laboratories creating forty CRDAs each per year over and estimated three year period. The metric is defined in macro factors as: [amount of dollars ($) invested by the outside partner] divided by [amount of dollars ($) invested by the federal partner]. The metric is applied one time at the mid-point of the agreement life and applicable to technology at various levels of maturity as demonstrated by simulations generated using statistical process control software by SPSS Inc.[41] The interpretation results and the conclusions of Mr. Hale's proposal and investigations through his eventual application to actual case studies represents the simple non-intrusive, e.g. easy to obtain data from industry partner and government unit, for eventual verification of any future technology transfer management prediction or decision making tools.

2.7 Not-for-profit academic institutions which operate technology research centers interfacing with industry are similarly task to determine their value and worth to the overall university or college. The inquiries[42] of Ashley Stevens, Boston University Community Technology Fund Director, into the measurement of technology transfer activities related to not-for-profit transactions provides the final piece of background information useful to this PDE. Stevens sites the difficulty with most technology transfer measures involving royalty income from licensing and patent fees as reflecting the results of transactions completed many years earlier and does not present a measure sufficiently sensitive of year-to-year changes. Stevens states, "I believe that the correct performance measure of a technology transfer office is the current total value to the institution of the transactions concluded in the year."[43] Stevens continues to propose that the best method to determine the total value to the institution is a simple and ideally used method of valuing a transaction as the total pre-commercial value, the sum of all the pre-commercial payments then apply a risk adjusted net present value (raNPV) method for valuing technologies. The essence of this approach involves "constructing a timeline of the development pathway that the technology must follow to reach the market, identifying some of the key milestones and move on to the next stage. By overlaying the financial structure of the transaction with this probability map, you obtain the probability that you will actually receive the payment ... obtain the net present value by discounting back to today using a 'cost of money' discount rate."[44] Stevens concludes that these calculations preformed with a simple Excel spreadsheet should be executed before transaction negotiations and are of value since a basis then exist which allows quantification of the

impact of trade-off opportunities which typically emerge. Considering the institution as a whole, the collective constructed time line/probability grid for all the transaction involving technology transfer could be added up as a portfolio for obtaining a final valuation. An annual picture of the valuation would simply show an increase or decrease of the net value.

2.8 The investigations of First Lieutenant Braun, the theoretical proposed metric and simulations of Mr. Hale, and the inquiries of Ashley Stevens together benchmark the current "state-of-the-science-and-art" of metrics for assessing the historical accomplishment of federal research laboratory projects or not-for profit institute programs involved with technology transfer. The next challenge is to provide laboratory management the decision making prediction methodology and tools applicable for assessing the technology transfer benefit available from current or planned primary mission related research. Once such methodology and associated engineering management tools are developed and administered, then the above candidate metrics have truly value added importance to research organizations. The goal of this PDE is to develop a management methodology, founded upon interdisciplinary human factors and statistical processes which would allow metrics to become useful management tools.

3.0 Methods

3.1 Methodology

3.1.1 The research plan for this study used action oriented experiential research and learning,[45] probability encoding[46] combined with the experimentation[47] statistical methods[48] championed by Dr. Donald J. Wheeler and used extensively in the Adaptation of the Air Force Materiel Command (AFMC) Metrics Course[49], and modeling and simulation. The method employed in the research leading to the PDE recognizes that technology transfer occurs through a management system possessing internal processes which take inputs and generatesoutputs under a set of constraints imposed from various sources. As do many systems which exhibit natural variations, the process of technology transfer is no different. Natural variations in input lead to variations in output. A diverse population of engineers and scientists evelop technology for specific roles and missions. The technology transfer opportunity provides for the diversion of military technology into new civil market products whose acceptance and product use is also a function of the interest, desires, and whims of a diverse population of investors, buyers, and users. The influence of the input on the output is not well understood and is subject to uncertainty. Testing educated estimates based upon known facts is the only opportunity to generate meaningful information for understanding the system or process by which technology is transferred; however, it requires knowledge of the imposed constraints and their relationship to an established strategy. Risk analysis represents a field of study which when combined with

encoded predictions of expert judges offers development of a cost estimate for technology transfer efforts to manage decision making processes. It is this predicted technology transfer cost estimate we seek for a selected focused group of technologies developed by WL to provide a management tool guiding future resource expenditures.

3.1.2 The method of research for this PDE is grounded in the residency seminars, new learning and internship which resulted in a strategy plan development experience[50] generating an understanding of the technology transfer process. The attainment of the goal stated in Section 2.8 would result in the development of a new management prediction tool verifiable through the selection of an appropriate metric. It is important to note that the definition of the word "metric" contained in the glossary of this document includes the key wording "drive appropriate action and must be linked to a strategic plan." Through fulfillment of The Union Institute internship residency requirement for The Doctor of Philosophy in Engineering Management, a review of current technology transfer processes was completed and a new more efficient and effective strategy[51] with appropriate task plan (Appendix 9.2) for implementation of an out reach program was developed and executed. The process addressed concerns of congressional mandates and federal law[52] affecting WL. It generated a new approach for technology transfer through out reach programs[53]. The creation of this new focus generated the authority and direction to organized the WL CRDA data files into statistically useful information (Appendix 8.3) for validating selected metrics. Ultimately this data set is of interest for consideration by any theorist attempting to produce engineering management tools

capable of assessing current technology programs not yet experiencing technology transfer efforts. The theoretical approach chosen introduces risk management analysis tools[54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68] to produce the desired performance indicators for technology transfer efforts tied to a strategy for technology transfer.[69]

3.2 Theoretical Approach

3.2.1 The theoretical approach in this study draws from the quality process design of experiments scientific method for investigation of multifactored inputs affecting the output of a particular process. Within the design of experiments approach to the scientific method recognized that the output of any process is affected by all possible factor combinations of inputs. Infact a factorial relationship usually exist generating unmanageable testing in many situations often resorting in the development of a random test matrix. Even the process of considering one factor at a time while holding all other factors constant generates a large expensive testing and analysis requirement upon the research investigator. The design of experiments (DOE) approach based upon the work of George Box, Charles Edward Deming, and Genichi Taguchi[70] provides the third option for analyzing cause and effect which incorporates knowledge and judgement, group problem solving techniques, and statistical tools. It requires adherence to the scientific method, viewed as a process. The general construct or model views the output of an experiment as being affected by multiple inputs, in which the influence of the inputs to the output is not well understood. During the design of the experiment the pretest review addresses the

process to be studied, identification of response variable(s) that the customer observes, a clear statement of the objectives in terms of the response variable(s), identification of the inputs and a selection of the interaction issue of the inputs. The use of DOE statistical tools requires that the response variables be measurable with numbers on a continuous scale and that we must be able to distinguish, separate and control the factors, e.g. inputs, which have independence. For this approach to be used in generating a term useful in the prediction of potential future technology transfer CRDAs from current R&D programs requires special development of a questionnaire and expert judgement response. The use of expert judges to evaluate the WL R&D programs in terms of known metrics while providing an estimated guess as to the potential yes (+1) or no (-1) for future successful technology transfer possibilities as an outcome of a natural processes exits through PE research interview processes.

3.2.1 PE as a reserach interview process allows for the opportunity to extract and quantify individual judgements about outcomes. PE has grown in popularity and is now commonly used in probabilistic decision analysis where uncertainity can be incorporated through the assignment of probability distributions to the variables or outcomes. By using PE the risk involved in quantifying responses from a test subject or expert judge can be accounted. Expert judgement or opinion is incorporated into the process, numbers are generated, and a probability distribution can be constructed for the provided estimates. The guidelines for using PE in the design of the experiment are: i) choose only uncertain quantities that are important to decision, ii) define the quantity as an unambiguous state variable, iii)

structure the quantity carefully so that it is understandable to the expert subject, iv) clearly define the quantity; and v) describe the quantity using a scale that is meaningful." From the data generated using these guidelines for questionaire development "... reasonable estimates and distributions can be constructed from uncertain quantitities."[71] PE minimizes the effect of human expert judgment which exhibits individual bias, either displacement bias, e.g. shift in distribution vertically, or variability bias, e.g. change in shape of distribution. This has been demonstrated and documented in literature via the PE method question development process based upon expert learned knowledge criteria.[72]

3.2.2 The specific achievable goal in the development of the engineering management tool for technology transfer, is the development of a method to estimate the WL technology transfer investment anticipated for facilitating the movement of technology from current R&D programs into future commercial products. Based upon previously proposed metrics presenting historical technology tansfer process data for WL programs, expert judges experientially identify active R&D programs according to the developed strategy for generating focused out reach groups. Risk assessment is introduced through a questionaire response incorporating a modified Air Force acquisition technology risk model. The model introduces WL technology transfer investment cost based upon past histroical data as experienced by the Air Force unit while incorporating schedule variations and uncertainity forcast interpreted as a risk factor. It is important to note that the use of the expert judge panel involves the PE neccessary components of motivation, structuring, conditioning, encoding, and verification in the initial process identifing potential WL R&D

programs. This process was key to data collection during the assessment phase of this research.

3.2.3 The classical motivation phase introduces the potential expert judge to the background and purpose of the decision making study. The motivation phase of this experimentwas accomplished through the selection of technology transfer focal point individuals within each directorate of WL who participated in the technology transfer strategy plan development and who, in addition, had experience in the development of CRDAs between Air Force units and industry partners.

3.2.4 The structuring phase of the PE process occurred during the creation of a questionnarie based upon aviable data from performance tracking measures of the CRDAs as well as the definition of the WL investment in the technology transfer activity as a numerical sum of scientist and engineer (S&E) encumberd salaries converted in FY97 dollars plus any charges for utilization of WL facilities as contained in the WL program management tracking database called "A Science & Technology Action Reporting System (ASTARS)." ASTARS contains 2,061 active R&D job order number data files.

3.2.5 The conditioning phase of the PE process occurred through the selection of currently funded and active R&D programs contained in ASTARS which most nearly matches the technology transfer strategy plan. The WL technology transfer focal points, i.e. strategy plan team members, which were selected as expert subjects for responding to

the questionnaire, generated the listing of current technology programs culled from the WL database applicable to the technology transfer out reach to general aviation (ORGA) focus group. Specifically, the experts utilized the National Aeronautics and Space Administration-Industry-Federal Aviation Administration Advanced General Aviation Transport Experiments (AGATE) Operation Requirements Document.[73] The experts were guided by their knowledge of the strategy task plan into thinking fundamentally about judgment and bias avoidance.

3.2.6 The encoding phase of the study quantified the important judgment of the expert choices in probabilistic terms which the verification review cross checked the validation of the selected research and development programs. The estimated potential dollar amounts of the WL investment into the technology transfer process for each program were summed for all expert judges and represent a collective outcome response in the DOE approach. An overall estimate of the WL technology transfer investment for the R&D programs were subsequently summed for a total Air Force investment value from the technology transfer ORGA suite of programs. When considered as an anticipated average per individual CRDA, the dollar amount was compared to proposed metrics presenting the past historical data.

3.2.7 The development of an appropriate technology transfer risk assessment schedule for impact upon cost was necessary. The risk factor values chosen by this Learner for technology transfer are found in the Air Force Quantified Risk Analysis (QRA) Criteria of

1993. This document concluded that risk categories for acquisition management technical/performance risk analysis include requirements, technology, engineering, manufacturing, support and managment.[74] The categories of technology, engineering, and manufacturing are technical in nature and address expert assessment in terms of questions: i) Is the technology [under consideration] available and proven in previous use? ii) How much new design is needed to achieve requirements? iii) Are the required manufacturing processes, facilities, and sources of materials known and available? Additionally, the Defense Systems Management College (DSMC) expands the description of technical risk to include issues of complexity/difficulty in meeting requirements, percent proven technology, experience in the field needed, lack of work on similar programs, special resources needed, operating environment, required theoretical analysis, degree of difference from existing technology , numerous state-of-the-art advances, lack of supporting state-of-the-art advances, integration/interface, reliability, and maintainability.[75] The DSMC guide depicts the important relationship between technical, cost, and schedule risk in the following figure[76].

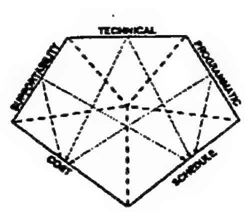

Figure 1. Risk Facets

3.2.8 Measuring cost risk, schedule risk, and technical risk presented unique challenges. Cost and schedule in terms of dollars and time are often combined using established statistical rules and techniques. Technical risk is diverse and no common unit of measure is fully accepted by industry and government. The combination of technical risk in weight, speed, range, weight, capacity, complexity, reliability, safety, temperature, vibration, etc. are specific to technologies and the application. However, students of risk assessment have developed methods to assess and describe technical risk through various specialized approaches: Narrative, Risk Templates ("Willoughby Templates"), Qualitative, Risk Scoring, Risk Scales, Maxwell Risk Criteria Marix, Technical Performance Measures, and System Maturity Matrix.[77] The QRA risk factors for technology in engineering acquisition management programs have traditionally been defined as:

0.01 Operational and deployed

0.20 In use by another program

0.50 Technology transition experiments successfully completed

0.70 Initial proof-of-concept experiments successfully completed

0.90 Basic research only. No development work

The risk definitions required modification (See Appendix 9.5) for this PDE. This modification was accomplished prior to the probability encoding interview questionnaire distribution to the expert judges. The modification was necessary due to the unique nature of technology transfer not being the primary mission goal of the individual R&D program under assessment. The questionnaire for this study was developed using cost information provided through the metric development process previously discussed and the QRA Risk Factors along with the modified definition for technology transfer by this Learner. Each expert required a prebrief about the assessment and the process by which they qualified as an expert, i.e., experience with WL R&D, CRDA, the WL Technology Transfer Strategy Plan, the "balloting" of existing CRDAs determining out reach program affiliation, and general familiarity with WL/XPT efforts to develop suitable metric(s) evaluating the success of technology transfer activities. The qualification of the expert judges was accomplished within the motivation, structuring, and conditioning requirements for PE prior to the collection of data. Each expert judge was expected to complete the questionnaire addressing individually the selected R& D programs from within their respective WL Directorates (i.e., Avionics, Flight Dynmanics, Manufacturing Technology, Materials, and Propulsion & Power).

3.2.9 The responses of the expert judges collectively represents a notable data set from which significant information was determined utilizing a DOE approach[78] to understanding the relationship of cost, schedule, and risk for technology transfer. The composite means for cost as affected by forcasted schedule and risk judgements

represented the "treatments"[79] and the result of completing the DOE process would resulted in a linear algebraic relationship predicting the WL invesment funding required to accomplish technology transfer CRDAs.

3.2.10 Applying this method to a specific set of cost, schedule, and time data from active R&D programs applicable to the Outreach to General Aviation strategy produced an estimate for future WL investment in technology transfer. Subsequent application to all focused out reach programs in technology transfer would represent a composite management prediction for risk adjusted investment to accomplish the CRDA process. The estimated investment term eventually could be compared to the median denominator term from the metric described in paragraph 2.6 Including uncertainty in a given project through risk management produces potential for forming the management bridge from understanding historical past events (metrics) to the future prediction of possible outcomes grounded in strategic planning and uncentainity expectations.

3.2.11 A review of Wright Laboratry CRDA files was accomplished by ten (10) WL technology transfer specialist and focal point representatives through a review and balloting process (Appendix 9.3). Those agreements which clearly represented technologies aligned with the task plan for the ORGA were identified and listed by industry partner name and CRDA number. Significantly, a data set relative to a strategy plan, now existed for use in developing new decision making and management tools. Seven (7) of the ten (10) WL technology transfer focal point scientist and engineers who

participated in the development of the WL Technology Transition and Transfer Strategic Plan[80] and the selection of focused technologies for the ORGA were provided an initial review of historical CRDA metric results[81] presented by Mr. Bill Hale. Based upon their strategic planning experience, familiarity with the task planning for the focused ORGA, and the CRDA metric; the expert judges were presented with a selection of currently active technology research and development (R&D) programs for review and execution of the questionnaire. This review was accomplished in accordance to the methods of PE which attempted to match the strategic plan goals with the expert's opinion as to potential for future CRDA development.

3.2.12 This review selecting technologies appropriate to the revitalization efforts of the U.S. general aviation industry involved the WL ASTARS database containing 2,061 unclassified R&D programs. The database was searched and a report generated which identified a subset of 135 current or recently completed R&D technology programs. These programs met future Air Force mission requirements while also matching the technology strategy task plan goals for the Technology Tranfer ORGA. Finally only open and active R&D programs were retained in the study with recent completed efforts eliminated from future consideration. The remaining fifty (50) R&D programs which were identified by Job Order Number (JON), schedule, funding, and technology transfer potential ratings are contained in Appendix 9.4. These programs prepresent the WL ORGA focused technology transfer opportunities. The study to determine the applicable information of significance to the strategy plan was completed and prepared for a Taguchi

Design of Experiment (DOE)[82] testing methodology. The Taguch DOE method involves processing experimental data, in this case the expert judge panel PE questionnaire response data, though an efficient set of DOE component tables, charts and arrays, i.e., data averages table, factors pivot table, pretest potential interactions array, L8 orthogonal array, L8 column assignment and results chart, linear model calculating coefficient results table, and finally the resulting linear model result equation chart.[83] The theory of the DOE method is well documented in literature and used extensively throughout the world in private, university, and government laboratory experimental research projects.

3.2.13 A Probability Encoding (PE) interview questionnaire was prepared (See Appendix 9.5) and distributed along with ASTARs data including R&D program objective, approach, and status descriptions to the expert judges on 3 - 4 June 1997. Individal interview pretest discussion with each expert judge was accomplished by the Learner. The responses from the expert judges were returned on or before 12 June 1997.

4.0 Findings

4.1 The encoded results are presented in Appendix 9.6. The data in column three (3) prepresents estimated possibility that the R&D program would (Yes = +1) or would not (No = -1) produce revenue generating technology transfer activity. This column is titled Technology Transfer Possibility (T2 Psblty). Note that expert judge probability encoding pretest interview process determined that a negative answer would still represent the remote possibility that the lowest level of technology transfer activity involving expert engineer consultation and advice from the WL could potentially result in a revenue generating CRDA. Previous experience with the development of a Mechanically Optimized Special Socket Wrench by The Main Corporation (TMC) under CRDA 94-272-WL-01with WL Flight Dynamics Structures Division (WL/FIBAD) resulted in a very small amount of WL manpower resouce expenditure yet produced revenues of ten cents ($.10) for the first 100k sold, ($.05) for the next 400K sold, and ($.02) thereafter. It is estimated that sales could exceed several million units per year. Thus negative responses (No) to question one (1) on the questionnaire were encoded upon the data sheet as (-1) response and accordingly question two (2) the estimated technology transfer investment as a percentage of the actual R&D program cost, question three (3) the technology transfer process schedule in months, and question (4) the technology transfer risk assessment factor were encoded on the form as A. 0.05% or .0005, A. Six (6) Months, and A. 0.01 Risk respectively. The data for question two (2) is found in column four (4) titled Technology Transfer Investment Percentage (T2 Invstmnt %), question three (3)

responses are in column five (5) titled Technology Transfer Months (T2 Mnths), and question four (4) responses are in column six (6) titledTechnology Transfer Risk (T2 Risk). Column seven (7) is the calculated estimate of required WL technology transfer resources to accomplish a revenue generating CRDA. Forty-nine (49) of the fify (50) questionnaires were returned by the expert judges. Note: The questionnaire for JON 24180260 was not returned while awaiting consultation of the expert judge with the project engineer to make the final selection of the answers to the questions. Repeated attempts to retrieve the information were unsuccessful to secure the form in a timely period for analysis. The remaining 49 questionnaires constitute a significant statistical sample from the original database of 2,061 R&D programs available for consideration. The column seven (7) computed amount of technology transfer investment in thousands ($K) is equal to the original R&D program cost which generated the technology for military purposes times the technology transfer investment percentage plus the same resulting amount times the risk factor:

Technology Transfer Estimated ($K) = R&D Prgm ($K) x T2 Invstmnt (%) x 100 +
[R&D Prgm ($K) x T2 Invstmnt (%) x 100] x T2 Risk (Nondimensional Unit)

This column is labled Technology Transfer Estimated $ K (T2 Estmtd $K).

4.4 The Taguchi Design of Experiments[84] methods of data processing involves the following components developed from the expert judge response information:

Number of Yes	9
Avg %	0.23%
Avg Mnths	10.875
Avg Risk	0.1333333

Table 1. Data Averages

The averages become the pivot points in the Design of Experiment factors array:

FACTORS	Level	Pivot	Level
	<		<
Possibility	-1	9	1
T2 $%	-1	0.23%	1
T2 Mths	-1	10.875	1
T2 Risk	-1	0.1333333	1

Table 2. Factors Pivot Table

The Design of Experiments pretest determination of the potential interactions are anticipated and assigned to the following matrix:

PRETEST	POTENTIAL	INTERACTIONS		
	T2 Psblty	T2 Invstmnt %	T2 Mnths	T2 Risk
T2 Psblty		YES	YES	NO
T2 Invstmnt %			YES	YES
T2 Mnths				YES

Table 3. Pretest Potential Interactions

The Taguchi Design of Experiment L8 orthogonal array assignment for the responses based upon the prestest potential interactions follows:

L8	C2	C3	C4	C5	C6	C7
C1	3	2	5	4	7	6
C2		1	6	7	4	5
C3			7	6	5	4
C4				1	2	3
C5					3	2
C6						1

Table 4 Taguchi Design of Experiments L8 Orthogonal Array

L8	GM	P	%	P%	T	R%	RP	R	EJ Grp #1	EJ Grp #2	....	EJ Grp #N
#1	1	-1	-1	-1	-1	-1	-1	-1	36.92358			
#2	1	-1	-1	-1	1	1	1	1	0			
#3	1	-1	1	1	1	1	-1	-1	0			
#4	1	-1	1	1	-1	-1	1	1	0			
#5	1	1	1	-1	-1	1	1	-1	0			
#6	1	1	1	-1	1	-1	-1	1	111.2725			
#7	1	1	-1	1	1	-1	1	-1	0			
#8	1	1	-1	1	-1	1	-1	1	0			

Table 5 L8 Column Assignments and Results of Expert Judge Group #1

The linear model calculating coefficients are determined from the L8 column assignments :

C1 =	18.52451		
C2 =	9.293615	P	-1
C3 =	9.293615	%	-1
C4 =	-18.52451	P%	-1
C5 =	9.293615	T	1
C6 =	-18.52451	R%	-1
C7 =	-18.52451	RP	-1
C8 =	9.293615	R	-1

Table 6 Linear Model Calculating Coefficients

The linear model produces the equation which results in the determination of the estimated WL investment for technology transfer necessary to achieve an anticipated nine (9) CRDAs for the ORGA from current R&D programs:

T2 ($K) = C1+C2*P+C3*%+C4*P%+C5*T+C6*R%+C7*RP+C8*R =	55.51081
Average T2 Estimated Investment per Anticipated Active (Yes +1) CRDAs =	6.167867778

Table 7 Linear Model Result: Wright Laboratory Technology Tranfer Estimated Investment for the Out Reach to General Aviation

5.0 Interpretation & Limitations

5.1 The calculated average technology transfer estimated risk adjusted resource investment per nine (9) CRDAs anticipated to occurr from the set of 49 selected R&D programs is determined to be $ 6,167.87. The aggrate total anticipated risk adjusted resources for the ORGA focused technology tranfer effort is $ 55,510.81 in fiscal year (FY) 1997 dollars. These results represent a single point in time evaluation obtained in the least most intrusive manner to the WL Scientists and Engineers.

5.2 The resulting linear equation model for predicting the risk adjusted aggregate total for the strategy plan out reach program prepresents the capability of the Taugchi Design of Experiments Method to analized data from minimally populated responses to achieve significant results. The combination of the probability encoding questionnaire technique for obtaining the responses of qualified expert judges still often result in a set of sparse data. Table 5 column ten (10) which is identified as Expert Judge Group #1 (EJ Grp #1) resulted in only two entries calculated from appropriate column data (Appendix 9.6) based upon the Design of Experiments L8 Orthorgonal Array.

5.3 The accuracy of the estimated risk adjusted technology transfer resource investment amount can be tracked by the simple metric of Job Order Number (JON) cost charged to CRDAs which develop in the future from the identified R&D programs in this study. To obtain a near term understanding for the success achieved by the linear model developed

through the results of the Design of Experiments approach we look to the previously mention work of Mr. Roy W. Hale (Paragraph 2.6). Mr. Hale's proposed Technology Transfer Metric Leverage Factor is defined as: [amount of dollars ($) invested by the outside partner] divided by [amount of dollars ($) invested by the federal partner]. In the case of WL, the denominator of this leverage factor would be an actual calculated amount of the from CRDA JON cost acount database. It is important to recall that the expert judges, who participated in this study, estimating the future risk adjusted WL technology transfer investment were the same experts who reviewed over 100 current files during the selection of CRDA's catagorized into the strategy plan focused out reach efforts, i.e. automotive, general aviation, medical, public safety, agriculture, etc. This CRDA catagory selection process was an integral part of the PE reqired motivation, structuring, conditioning, and verification research interview components. The selection of the current CRDA's applicable to the ORGA are found in Appendix 9.4 This set of historical data represents an approximation to information available for comparison with the newly developed risk adjusted WL technology tranfer investment estimate for future R&D programs. Twenty-four (24) of sixty-one (61) CRDA's had available mid-term data for use in calculating the metric technology transfer leverage factor. This single point assessment as of May 2, 1997 for the applicable ORGA CRDA's determined that the median WL investment per CRDA was $ 6,045.00 while the mean was $ 10,585.50. Comparing these investment terms from current general aviation related WL CRDA's to the estimated mean for future potential general aviation CRDA's from the WL R&D programs ($ 6,167.87), provides confidence that future tracking of WL CRDA cost data against the estimated

technology tranfer investment is warranted.

5.4 There are limitations to this PDE developed management methodology resulting from the combination of a metric, strategic plan, PE, risk management, and the Taguchi DOE technique for program management. Although the metric may be as simple or complex as the user desires it must be clearly related to the strategic plan of the organization seeking to implement the management methodology. A strategic plan development or review, study, and evaluation must involve the cadre of potential expert judges prior to the PE interviewing research data collection process. The candidate expert judge involvement within the implementing organization's strategic planning processe fulfills the PE expert judage pannel qualification requirements. Additionally, the interview questionnaire must be simple and non-intrusive while obtaining data definable within the DOE interaction array of possibilities. Finally, a limitation of the DOE technique is found in its application to cause and effect relationships of experimental processes. Additionally, in this PDE one set of data was not returned in a timely manor to be included in the analysis. Subsequent last minute inspection of the missing data noted that an additional cell in Table 5 would have been generated increasing the final calculated value reported in Table 7 achieving an improved correlation with the leverage factor denominator of the chosen technology transfer metric.

6.0 Conclusions & Recommendations

6.1 The management of technology transfer process now has available a new methodology for key decisions makers. The effective metric[85, 86] which measures the cost of the conversion process from research to manufacturing now combined with a prediction method incorporating risk assessment of new technology for future transfer agreements resulting from this PDE. These affordable non-intrusive methods which rely heavily upon the science of statistics within the PE and the Taguchi DOE methods of research provide new tools necessary for understanding cost and impact of technology transfer activities of federal research laboratories.

6.2 The opportunity to involve additional expert judge panels composed of representatives from each directorate would enhance the quantity of data by providing additional calculated entries into the columns reserved for EJ Grp # 2 through EJ Grp # N of Table 5. However; increasing the number of expert judge panels increases the intrusion into the work force routine potentially introducing an artifical disruption of the process being investigated. Future meaningful studies appropriate for a Doctorate of Philosophy PDE would be the use of probability distributions to complete the data within column ten (10) of Table 5 labeled L8 Column Assignments and Results of Expert Judge Group #1. In this manor the nonintrusive nature of the research could be maintained while providing statistically important refinement to the linear equation result (Table 7) predicting the WL technology transfer investment from future R& D programs. Overall validation of the

technology transfer risk assessed investment linear equation predicition methodology would be appropriate for student reserach projects leading to several master thesis investigating predicitons for each of the WL focused outreach programs i.e, automotive, medical, agriculture, public safety, in addtion to the general aviation. Such a reserach activity could conceivably extend for a period of three to five years to yield comparative predictions resulting from additonal expert judge panels. The WL metric leverage factor denominator term would similarly become more vaild with additional years of data and experience. The combination of the management tools into this new methodology demonstrates an interdisciplinary nature in that human factors and statistical processes combine through the identified components to produce a quantified measure predicting future results. Managers, with a metric at hand, now have a scientific method for decision making about future program investments.

7.0 Endnotes

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9.0 Appendices

9.1 Example CRDA Benefits Data

CRDA Tracking Number: 95-201-WL-01

Company Involved: Paragon Aircraft

Point of Contact/Office Sym/Phone #:

Purpose: Analyze and develop the design of a single turbo-fan engine aviation aircraft which has the following attributes:

- Inlet over the fuselage, a high aspect ratio straight wing and utilizes a composite structure
- Performance analysis will refine the aerodynamic characteristics of a new air flow and will work to ensure the structural integrity of the composite airframe

Identify All the expected benefits received from the CRDA:

1. Flight Dynamics Branch gaining increased experience in CFD and Flutter analysis and ground vibration tests

2. Usable test data derived from the CRDA--test conducted here at WPAFB

3. Wind tunnel testing still to be conducted (future of the facilities may be in jeopardy this CRDA provides additional justification to keep this facility operational)

4. Royalty stream expected to recoup man hr. expended during this CRDA.

Provide a quantified estimate of each benefit mentioned above in terms of dollars saved/received, man hr. saved, or time saved.

CRDA # 95 - 201 - WL - 01
Company: Paragon Aircraft in conjunction with WL Flight Dynamics Branch

Expected Benefits	1996	1997	1998	1999	2000	2001	Net Present Value at 7%
Royalty Stream	$ -	$ -	$ -	$ 51,622	$ 98,514	$ 37,465	
- Aircraft Sold	0	0	0	2.671945	5.099084	1.939162	
- Rev. per Aircraft	$ 19,320	$ 19,320	$ 19,320	$ 19,320	$ 19,320	$ 19,320	
Payment for testing		$801,417					
* *Fatigue and Static test to be conducted at WL facility*							
Total Revenue	$ -	$801,417	$ -	$ 51,622	$ 98,514	$ 37,465	
Present Value at 7%	$ -	$699,988	$ -	$ 39,382	$ 70,239	$ 24,964	$ 834,574

Identify all of the benefits received through CRDA relationship that were not originally spelled out in the agreement:

1. The CRDA provided an opportunity to demonstrate and validate existing capabilities at WL for a whole airplane
   - Additional breadth gained by conducting developmental testing on an entire aircraft

2. The CRDA helped to justify the resources used to do testing on the aircraft

3. Insight gained into the commercial aircraft industry--the feeling was that WL had lost touch with the civilian aircraft market; this CRDA helped us get our foot in the door and gain additional insight into the civilian aircraft industry

4. Fatigue and static test to be conducted at WL structures test facility--Facility contractor will receive payment for testing conducted at WL as well as additional work that will help to smooth out the testing schedule. Additional knowledge will be gained in the area of flutter analysis

* Paragon will pay the total costs of static testing to the contractor that runs the structure test facility.

Identify any nonquantifiable benefits received by the Air Force as a result of the CRDA :

- Public relations benefit--goodwill towards the military and Air Force in general

- Provides insight into the FAA certification process--this will provide WL the opportunity to see another approach to solving problems

- Increased capability at lower costs

Identify any lessons learned about the CRDA process during the development of this CRDA

- Mutually beneficial agreement where both sides pursued the agreement and are actually working to achieve a desired outcome.

Crystal Ball Report
Simulation started on 7/16/96
at 15:32:38
Simulation stopped on 7/16/96
at 15:33:02

Forecast: Present value of Paragon CRDA

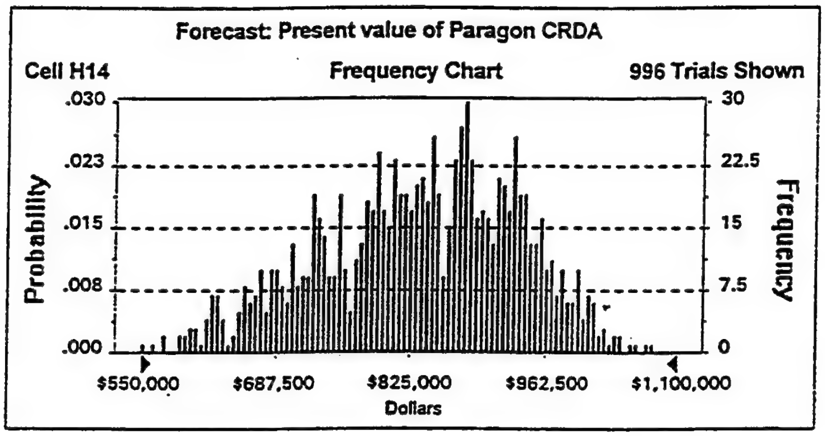
Summary
:

Display Range is from $550,000 to $1,100,000 Dollars
Entire Range is from $523,003 to $1,076,825 Dollars
After 1,000 Trials, the Std. Error of the Mean is $3,237

Statistics
:

Value

Trials	1000
Mean	$834,574
Median (approx.)	$843,481
Mode (approx.)	$935,600
Standard Deviation	$102,354
Variance	$10,476,257,251
Skewness	-0.35
Kurtosis	2.60
Coeff. of Variability	0.12
Range Minimum	$523,003
Range Maximum	$1,076,825
Range Width	$553,822
Mean Std. Error	$3,236.70



Forecast: Present value of Paragon CRDA (cont'd)

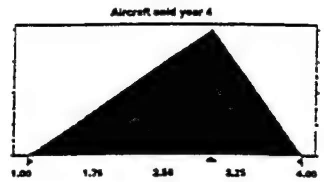
Percentiles:

Percentile	Dollars (approx.)
0%	$523,003
10%	$690,380
20%	$740,839
30%	$786,464
40%	$814,682
50%	$843,481
60%	$873,552
70%	$896,525
80%	$928,348
90%	$958,340
100%	$1,076,825

Assumption: Aircraft sold year 4

Triangular distribution with parameters:

Minimum	1.00
Likeliest	3.00
Maximum	4.00



Selected range is from 1.00 to 4.00
Mean value in simulation was 2.67

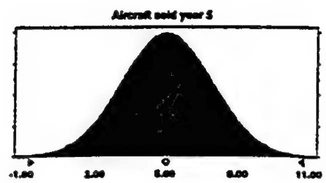
Correlated with:

Aircraft sold year 5 (F7)	0.25
Aircraft sold in year 6 (G7)	0.15

Assumption: Aircraft sold year 5

Normal distribution with parameters:

Mean	5.00
Standard Dev.	2.00



Selected range is from -Infinity to +Infinity
Mean value in simulation was 5.10

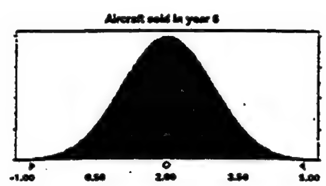
Correlated with:

Aircraft sold year 4 (E7)	0.25
Aircraft sold in year 6 (G7)	0.25

Assumption: Aircraft sold in year 6

Normal distribution with parameters:

Mean	2.00
Standard Dev.	1.00



Selected range is from -Infinity to +Infinity
Mean value in simulation was 1.94

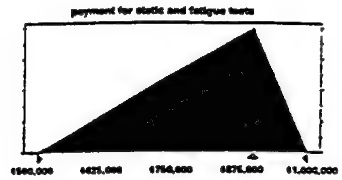
Correlated with:

Aircraft sold year 4 (E7)	0.15
Aircraft sold year 5 (F7)	0.25

Assumption: payment for static and fatigue tests

Triangular distribution with parameters:

Minimum	$500,000
Likeliest	$900,000
Maximum	$1,000,000



Selected range is from $500,000 to $1,000,000
Mean value in simulation was $801,417

9.2 Outreach to General Aviation Task Plan

U.S. AIR FORCE WRIGHT LABORATORY
PLANS & PROGRAM DIRECTORATE
TECHNOLOGY TRANSFER & TRANSITION
STRATEGIC PLAN

Task Plan: Outreach to General Aviation

Relevant Action Plan: Expand Outreach Programs

Focal Point: Mr. Lanny A. Jines P.E. (jinesla@wl.wpafb.af.mil)

Objective: Assist the U. S. General Aviation Industry to achieve World Market Leadership in the design, development, and manufacturing of all category and class of aircraft through technology transfer and transition while insuring military readiness via sustained availability of advanced aerospace technology production capability and capacity.

Assumptions: The General Aviation Revitalization Act (S.1458) of 1994 signed by The President reform federal tort law establishes an eighteen (18) year statue of repose in aircraft accident lawsuits. This precedent setting legislation provides the general aviation industry new opportunities for original equipment manufacturers (OEM), after market vendors, modification facility operators, and material suppliers to design, develop, test, and market advanced state-of-the-art technology improvements in materials, manufacturing processes and aircraft designs for flight, ground, and training systems. Wright Laboratory's technologies combined with the design, production, and market share capabilities of the General Aviation Industry would reduce development and life cycle costs of militarily important advancements.

Approach: Market WL technology transfer and transition opportunities through the Advanced General Aviation Transport Experiments (AGATE) Program. This program is a consortium composed of NASA, FAA, and General Aviation Industry. Additionally, establish a Technology Transfer Outreach to General Aviation category within the Internet World Wide Web (WWW) WL Home Page . Post and maintain on the WWW current list and description of applicable points of contact and technologies ready for transfer to general aviation. Focus and control outreach opportunity to capitalize upon U.S. Air & Trade Show for WL technology and facility marketing and exhibition.

Air Force Relevance: The advanced technologies in materials, structures, propulsion, flight control, avionics, cockpit, subsystems, and training are common to all aircraft systems, military and civilian general aviation alike, seeking to meet customer need for improved safety, performance, and efficiency. The timely and cost effective availability of materials, manufacturing facilities, skilled work force and proven systems integrated

performance important to Air Force weapon systems (i.e. commercial available products for direct military use) is directly related to the proliferation of aircraft design, production, operations, and training systems in a modern state-of-the-art United States manufactured general aviation fleet competitive in the world market.

Payoff: The General Aviation Industry should benefit by having access to WL technologies and resources while the Air Force shall have access to "smarter, cheaper, better" aircraft flight systems, propulsion sensors and controls, integrated design and manufacturing, icing protection systems, integration platforms for flight testing, air infrastructure strategies, ground infrastructure improvements, advanced technology training systems, and aerodynamic acoustic improvements for future military systems. Additional payoff to the Air Force includes the access to stronger more competitive domestic manufacturing industrial base with a work force of compatible and relevant skills available when military needs arise.

Schedule:

Major Activity	Start	Complete
Preparation/Planning	02 JAN 96	28 FEB 96
Core PAT	01 MAR 96	30 MAR 96
WL Technology Identification Process	01 APR 96	ON-GOING
GA Technology Need Identification Process (FAA/NASA/ GA Industry T3 Visits)	01 APR 96	ON-GOING
General Aviation (GA) Outreach Home Page	01 MAY 96	30 MAY 96
SBIR & CRDA Development	01 JUN 96	ON-GOING
GA Outreach Functional IOC	01 JUN 96	ON-GOING
AGATE Membership	31 JUL 96	ON-GOING

9.3 CRDA Ballot Data

Company	CRDA No.
Night Vision Eqpt PA	92-281-1W
Lockheed FW TX	93-126-wl-01
Superconductive Comp OH	94-178-wl-02
Shaw Custom Sys's CA	94-241-wl-01
Loral Defense System OH	95-009-wl-01
Am'cn CompTech OH	95-332-wl-01
Adtech Sys Res Lab OH	96-101-wl-01
Gauge & Measure OH	94-010-wl-01
Northrop Elect Sys IL	94-178-wl-01
VPI	92-175-IAF
Firefox Industries PA	94-173-wl-01
Artificial Horizons CA	94-173-wl-02
Rockwell Int'l Corp CA	94-242-wl-02
The Main Corporation CO	94-272-wl-01
Smiths Industries FL	94-327-wl-01
Cold Jet OH	94-336-wl-01
Aviation Envi'l Comp OH	95-075-wl-01
Fatigue Concepts CA	95-075-wl-02
Lear Astronics Corp CA	95-093-wl-01
Metrolaser CA	95-170-wl-01
Adtech Systems OH	95-192-wl-01
Universal Analytics CA	95-192-wl-02
Century Aerospace NM	95-201-wl-01
Intern'l Mktg Inc PA	95-214-wl-01
Systran Corp OH	95-222-wl-01

Hughes Danbury CT	95-319-wl-01
Textron Spec'y Matls MA	96-005-wl-01
Hitco Techn'ies Inc CA	96-130-wl-01
Rapco Fleet Serv's WI	96-134-wl-01
Univ of Missouri MO	96-222-wl-01
Adtech Sys Rsrch OH	96-323-WL-01
Adtech Systems OH	89-01
Daychem OH	90-01
Purdue University IN	91-01
Adtech Systems OH	91-02
Performance Plastics OH	93-099-wl-01
Process Eqpt Co. OH	93-207-wl-01
Ribbon Technology OH	93-250-wl-01
General Electric NY	93-267-wl-02
General Electric NY	93-351-wl-01
Technosoft Corporati OH	94-012-wl-01
Armco Inc. OH	94-130-wl-01
Techy Assm't & Trans MD	94-132-wl-01
Atlantic Research MA	94-171-wl-01
Modern Techn'ies OH	94-242-wl-01
Edison Polymer Inc OH	94-340-wl-01
Applied Science Inc OH	95-004-wl-01
U. of Rochester. NY	95-156-wl-01
Hohman Plat'g/Mfg OH	95-335-wl-01
Laser Photonics NY	96-030-wl-01
Process Eqpt Cofp OH	96-099-wl-01

Century Aerospace	NM	96-149-wl-01
Maxdem Inc.	CA	96-156-wl-01
TCAM Tch'ies Inc.	OH	96-271-WL-01
RJO	OH	93-267-wl-01
GE Acft Engines	OH	93-208-wl-01
Davis Engineering	TN	93-221-wl-01
Allied Signal Contro	IN	94-038-wl-01
Solar Turbines Inc.	CA	96-078-wl-01
GE Acft Engines	OH	96-145-wl-01

9.4 ASTARS Data for Matching WL R&D Technologies

JON	Begin	End	R&D $ K	T2 Potential
43472403	1-Mar-96	31-Dec-97	135	HI
300505Q6	1-Mar-95	1-Mar-97	275	HI
43471102	1-Jun-96	30-Sep-00	1082	HI
300505R6	1-Feb-96	31-Dec-99	643	HI
43476107	1-Jun-95	30-Sep-98	300	LO
2302P101	1-Oct-84	30-Sep-99	1558	LO
31530015	1-Aug-94	31-Dec-00	2837	LO
31530016	1-Aug-94	31-Dec-97	951	HI
43494102	31-Jan-96	30-Jun-98	35	LO
4349S101	1-Sep-96	30-Apr-03	1355	HI
43494401	3-Jan-95	30-Sep-98	676	HI
24180260	1-Oct-92	30-Sep-99	896	LO
24180485	10-Aug-92	30-Oct-97	1684	LO
24184005	1-Sep-93	30-Aug-99	4339	HI
24184008	1-Apr-93	31-Mar-97	737	LO
24184012	1-Dec-93	30-Dec-96	165	HI
24184017	15-Jul-94	30-Jun-97	193	HI
30050581	14-Jun-93	30-Mar-98	822	LO
43494001	1-Sep-96	30-May-03	4992	HI
300505AB	15-Mar-94	31-Dec-97	738	HI
24803000	13-May-92	31-Jan-98	2075	LO
24803050	24-Nov-93	30-Dec-99	1630	LO
24803051	1-May-94	30-Dec-99	560	LO
24803052	1-May-94	30-Dec-99	157	LO
24803054	1-May-94	30-Dec-99	893	LO

30480537	1-Oct-83	30-Sep-98	1350	LO
304805AJ	1-Oct-92	30-Sep-97	2013	LO
314501C6	5-Nov-91	30-Jun-97	2954	LO
314501C8	2-Jun-93	30-Mar-98	674	LO
314520C3	13-May-93	30-Sep-97	652	LO
314529LA	19-May-93	31-Aug-98	521	LO
314532Y4	1-Jun-93	30-Sep-97	576	LO
2303BW1Q	1-Oct-95	30-Sep-99	105	N
30480618	1-Apr-72	1-Sep-99	1093	LO
30950126	1-Sep-93	31-Aug-99	3175	HI
30950530	28-Feb-93	30-Sep-97	2000	LO
30950113	5-May-91	30-Sep-97	23424	LO
CRDF9507	1-Oct-95	1-Oct-99	7	HI
30054192	15-Aug-95	30-Sep-98	555	LO
30054191	15-Aug-95	30-Sep-98	450	LO
ARPAAA09	25-Aug-95	26-Feb-98	754	HI
76620166	3-Jan-94	31-Dec-99	841	HI
25060701	1-Nov-89	30-Sep-97	3317	N
24030159	13-Apr-92	30-Dec-97	4906	LO
2403015J	1-Jul-94	30-Sep-98	17.5	HI
2403015U	1-Feb-96	1-Jun-97	300	HI
2403015V	21-Mar-96	30-Mar-97	225	N
3005F000	29-Dec-95	15-Feb-98	750	LO
2302BW2P	1-Oct-95	30-Sep-97		LO
300505AB	15-Mar-94	31-Dec-97	738	HI

9.5 Probability Encoding Questionnaire

Subject: Assessment of Wright Laboratory R&D Program Potential Technology Transfer

Focused out reach efforts are identified in the Wright Laboratory Technology Transfer and Transition Strategy Plan. They exist to assist the U.S. industrial manufacturing base sustainment of world market leadership. The task plan for the Out Reach to General Aviation resulted from theWright Laboratory strategy. Through your assistance, the Wright Laboratory Directorates recently reviewed their current R&D technology programs which exhibited strong relationship to the operational requirements of the NASA - Industry - FAA Advanced General Aviation Transport Experiments (AGATE) program for revitalization of the general aviation industry. The response of the directorates resulted in a listing of technology programs, facilities, and expertise which would represent the Wright Laboratory capability for technology transfer assistance to the general aviation industry. The ASTARS database contains information about the identified programs.

R & D Program ASTARS JON: ________________

1. In your expert opinion does the R&D program (See ASTARS JON Data) exhibit potential for transfer of technology to an industry partner resulting in the generation of revenue via a CRDA fee, Patent fee, or License fee.

A. Yes B. No (If No then skip remaining questions proceed to next ASTARS report)

2. In your expert opinion which level of Air Force investment would be required to bring about the transfer of technology from the R&D program under consideration. The levels are stated as a percentage or decimal factor of the **R&D program total cost** as shown in the ASTARS report. Note: The **median** Wright Laboratory investment per General Aviation Out Reach CRDA for the technology tranfer efforts of Air Force unit scientist and engineers ha s been determined to be $ 6,045.

A. 0.05 % or .0005 B. 0.10 % or .001 C. 1.0 % or .01

3. In your expert opinion which of the following schedule periods would most likely allow for anticipated R&D program technology transfer to an industry partner. (ASTARS progress reports may be useful)

A. Six (6) Months B. Eighteen (18) Months C. Thirty-six (36) Months or longer

4. In your expert opinion please assign a technology transfer risk assessment value to the R&D program. (Note: The ASTARS report in some cases has an input for Technology Transfer potential provided by the Project Engineer. You may generally agree or disagree with theASTARS information)

A. 0.01 One or more CRDAs already exist based upon this technology R&D program.

B. 0.2 The R&D program has previously produce technology transfer activities which have been completed (CRDA fulfilled or expert assistance provided) but some effort required for new applications.

C. 0.5 At the end of the scheduled period noted in question three (3), the technology transfer activity could produce a technology for manufacture or use in production processes.

D. 0.7 The R&D program is a proof of concept. Reasonable effort would be required to bring about transfer of technology into new product or manufacturing process.

E. 0.9 The R&D program is basic research. Significant effort would be required to bring about transfer of technology into new product or manufacturing process.

9.6 Questionnaire Results

JON	R&D Prgm $ K	T2 Psblty	T2 Invstmnt %	T2 Mnths	T2 Risk	T2 Estmtd $K
24180260	896	NA	NA	NA	NA	#VALUE!
43472403	135	-1	0.05%	6	0.01	0.068175
300505Q6	275	-1	0.05%	6	0.01	0.138875
43471102	1,082	-1	0.05%	6	0.01	0.54641
300505R6	643	-1	0.05%	6	0.01	0.324715
43476107	300	-1	0.05%	6	0.01	0.1515
2302P101	1,558	-1	0.05%	6	0.01	0.78679
31530015	2,837	-1	0.05%	6	0.01	1.432685
31530016	951	-1	0.05%	6	0.01	0.480255
43494102	35	-1	0.05%	6	0.01	0.017675
4349S101	1,355	-1	0.05%	6	0.01	0.684275
43494401	676	-1	0.05%	6	0.01	0.34138
24180485	1,684	-1	0.05%	6	0.01	0.85042
24184005	4,339	-1	0.05%	6	0.01	2.191195
24184008	737	-1	0.05%	6	0.01	0.372185
24184012	165	-1	0.05%	6	0.01	0.083325
24184017	193	-1	0.05%	6	0.01	0.097465
30050581	822	-1	0.05%	6	0.01	0.41511
43494001	4,992	-1	0.05%	6	0.01	2.52096
300505AB	738	-1	0.05%	6	0.01	0.37269
24803000	2,075	-1	0.05%	6	0.01	1.047875
24803050	1,630	-1	0.05%	6	0.01	0.82315
24803051	560	-1	0.05%	6	0.01	0.2828
24803052	157	-1	0.05%	6	0.01	0.079285
24803054	893	-1	0.05%	6	0.01	0.450965
30480537	1,350	-1	0.05%	6	0.01	0.68175
304805AJ	2,013	-1	0.05%	6	0.01	1.016565
314501C6	2,954	-1	0.05%	6	0.01	1.49177
314501C8	674	-1	0.05%	6	0.01	0.34037
314520C3	652	-1	0.05%	6	0.01	0.32926
314529LA	521	-1	0.05%	6	0.01	0.263105
314532Y4	576	-1	0.05%	6	0.01	0.29088
2303BW1Q	105	-1	0.05%	6	0.01	0.053025
30480618	1,093	-1	0.05%	6	0.01	0.551965
30950126	3,175	-1	0.05%	6	0.01	1.603375
30950530	2,000	-1	0.05%	6	0.01	1.01
30950113	23,424	-1	0.05%	6	0.01	11.82912
76620166	841	-1	0.05%	6	0.01	0.424705
24030159	4,906	-1	0.05%	6	0.01	2.47753
2302BW2P	0	-1	0.05%	6	0.01	0
CRDF9507	7	1	1.00%	18	0.01	0.0707
25060701	3,317	1	1.00%	18	0.7	56.389

30054192	555	1	1.00%	36	0.7	9.435
30054191	450	1	1.00%	36	0.7	7.65
2403015J	18	1	1.00%	36	0.7	0.2975
2403015U	300	1	1.00%	36	0.7	5.1
2403015V	225	1	1.00%	36	0.7	3.825
ARPAAA09	754	1	1.00%	36	0.9	14.326
3005F000	750	1	1.00%	36	0.9	14.25